PB90-215799

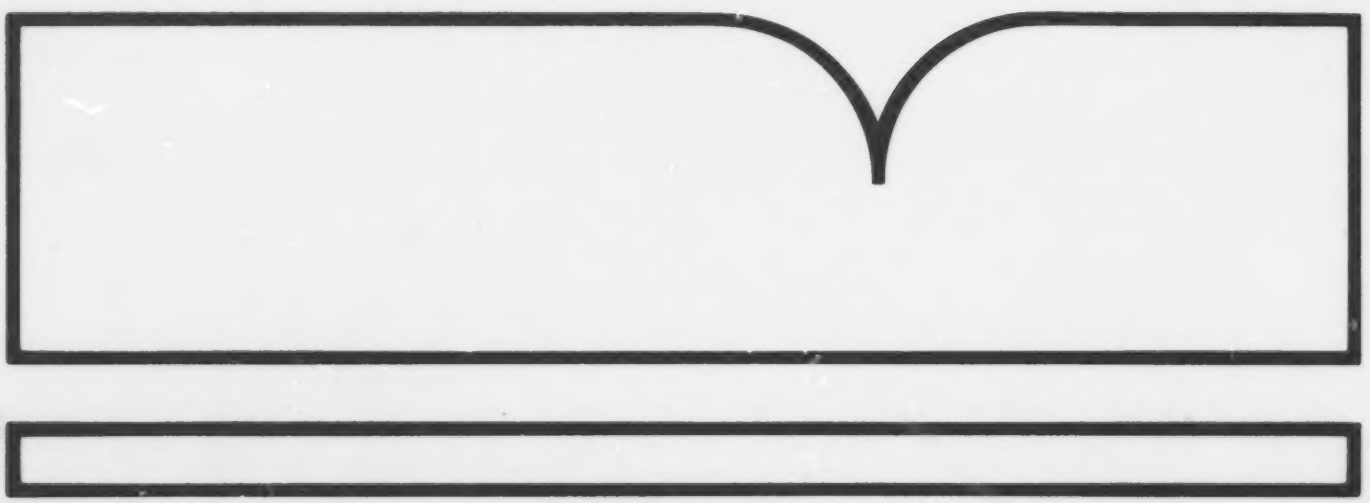
Galvanized Steel: National Distribution Study

Aerocomp, Inc., Costa Mesa, CA

Prepared for:

Environmental Protection Agency, Research Triangle Park, NC

May 90



U.S. Department of Commerce
National Technical Information Service
NTIS

EPA/600/3-90/039
May 1990

PB90-215799

GALVANIZED STEEL

NATIONAL DISTRIBUTION STUDY

BY

John H. Crouch and Joseph A. Catalano

Aerocomp, Inc.

3303 Harbor Boulevard

Costa Mesa, CA 92626

Contract No. EPA 68-02-4470

Project Officer

Fred H. Haynie

Chemical Processes and Characterization Division

Atmospheric Research and Exposure Assessment Laboratory

U.S. Environmental Protection Agency

Research Triangle Park, NC 27711

ATMOSPHERIC RESEARCH AND EXPOSURE ASSESSMENT LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/3-90/039		PB90 215799/AS

4. TITLE AND SUBTITLE	5. REPORT DATE
GALVANIZED STEEL: NATIONAL DISTRIBUTION STUDY	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
J. H. Crouch and J. A. Catalano	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Aerocomp Inc. 3303 Harbor Boulevard Costa Mesa, California 92626	N104/G/04/-02 (FY-89) 11. CONTRACT/GRANT NO. 68-02-4470

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Atmospheric Research & Exposure Assessment Lab Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711	Project Report 14. SPONSORING AGENCY CODE EPA/600/09

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report describes a field survey done to observe the extent and application of bare galvanized steel in the United States. For purposes of the analysis, the conterminous 48 states were grouped into four regions. Industrial and rural areas were considered in the study which examined galvanized steel applications of roofing, siding, gutters and flashing, transmission line towers, fencing, pole line hardware, guardrails, and storage facilities. A field survey was conducted in four cities thought to be representative of each region for visual inventory. In-house surveying was then performed using aerial photography corresponding to the areas visited and relevant land use data to calculate surface area of the observed galvanized steel. Extrapolation to entire metropolitan areas was done through the land use statistics. Estimates of galvanized steel surface in non-residential urban areas from the survey observations are 9.2×10^4 m^2 for Cleveland, 53.8×10^4 m^2 for Atlanta, 38.6×10^4 m^2 for Dallas, and 256.8×10^4 m^2 for Sacramento.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	58
	20 SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

DISCLAIMER

Although the work in this document has been funded wholly or in part by the United States Environmental Protection Agency under contract number 68-02-4470 to Aerocomp, Inc., it does not necessarily reflect the views of the agency and no official endorsement should be inferred.

ABSTRACT

This report describes a field survey done to observe the extent and application of bare galvanized steel in the United States. For purposes of the analysis, the conterminous 48 states were grouped into four regions. Industrial and rural areas were considered in the study which examined galvanized steel applications of roofing, siding, gutters and flashing, transmission line towers, fencing, pole line hardware, guardrails, and storage facilities. A field survey was conducted in four cities thought to be representative of each region for visual inventory. In-house surveying was then performed using aerial photography corresponding to the areas visited and relevant land use data to calculate surface area of the observed galvanized steel. Extrapolation to entire metropolitan areas was done through the land use statistics. Estimates of galvanized steel surface in non-residential urban areas from the survey observations are 9.2×10^4 m^2 for Cleveland, 53.8×10^4 m^2 for Atlanta, 38.6×10^4 m^2 for Dallas, and 256.8×10^4 m^2 for Sacramento.

CONTENTS

Abstract iii
Figures v
Tables vi
Acknowledgments vii

1. Introduction 1
2. Background and Approach 3
   2.1 Overview of Inventory Activities 4
   2.2 Maintenance Practices and Costs 6
   2.3 Methodology 8
3. Survey Method 10
4. Regional Summary 16
   4.1 Residential Gutters, Flashing and Fencing . 20
   4.2 Transmission Line Towers 21
   4.3 Pole Fixtures 24
   4.4 Highway Guardrail and Fencing 25
5. In-Place Summaries by Application 32
6. Suggestions for Further Study 36
7. References 37

Appendixes

A. Description of Survey Activities 40
B. Residential Galvanized Surfaces 49
C. Highway Guardrail Length 51

FIGURES

Number		Page
1	Region Subdivisions in the Study	11
2	Guardrail Regression Lines, Northeastern and Southeastern Regions	29
3	Guardrail Regression Lines, Western and Central Regions	30

TABLES

Number		Page
1	Non-Residential Urban Bare Galvanized Steel Distribution	16
2	Farm Bare Galvanized Steel Distribution	18
3	Residential Exterior Galvanized Surface Area	21
4	Transmission Towers in Place	23
5	New York Transmission Line by Utility	24
6	Sacramento and Cleveland Galvanized Pole Fixtures	25
7	Guardrail Length Regression Equations	27
8	Non-Residential Urban Galvanized Steel Distribution	32
9	Bare Galvanized Steel Distribution per Farm	33
10	Regression Through Origin of Galvanized Steel for Non-Residential Urban Land Area	34
11	Regression Through Origin of Galvanized Steel for Farms	34
12	Non-Residential Urban Land Area by City	35
13	Estimate of Galvanized Steel for Non-Residential Urban Land Area	35
B1	Single Family Residential Exterior Materials	49
B2	Multi-Family Residential Exterior Materials	50
C1	Highway Guardrail Length	51

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Mr. John W. Spence, Mr. Joel Scheraga and Mr. Philip Baedecker for helpful comments regarding aspects of the work presented here. Special mention is made to Ms. Pauline G. Crouch who participated in field surveys, and Mr. Fred W. Lipfert who shared his experiences and various technical reports on the subject. Support of Aerocomp by the Environmental Protection Agency Contract No. 68-02-4470 is also gratefully acknowledged.

1. INTRODUCTION

It has long been recognized that air pollution and acidic deposition cause corrosion of materials (e. g., Larrabee et al., 1959); for instance, gaseous and particulate pollutants can react with the protective coating of galvanized products to reduce their life span. This effect causes economic loss by reducing the useful life of products. An effective assessment of costs due to air pollution materials damage involves many variables and uncertainties. One of the variables needed for cost assessment is the distribution of sensitive materials (i.e., total quantities in place, their geographic distribution, application, and maintenance practices).

This project, National Distribution of Galvanized Steel Products, was conducted for Task Group VII, Effects on Materials and Cultural Resources, within the National Acid Precipitation Assessment Program (NAPAP). Information on the distribution of galvanized steel products will be used by NAPAP in preparation of the 1990 Assessment Report to Congress.

The overall objective of the study was to observe the extent and applications of bare galvanized steel in various regions of the country. Applications considered were roofing, siding, gutters and flashing, pole line hardware, storage facilities, transmission line towers, guardrails, and fencing.

For purposes of the study, the adjoining 48 states were grouped into four regions: Northeast, Southeast, Central, and West. Four cities, each thought to be representative of a region, were visited. Cleveland, Atlanta, Dallas, and Sacramento were selected as representative locations, and a ground survey was undertaken to include commercial, industrial and rural lands. Extensive notes were taken in the field; additionally, about 170 photographs were taken. The ground-truth surveys were complemented with aerial

photography. Structure sizes were calculated from both aerial view and the scaled photographs taken in the field. Results were assembled into a data base which produced totals by application and land type for each metropolitan area visited.

Section 2 of this report contains general information regarding material damage, prior inventories of material in place, maintenance practices, and a description of steps in the study. Section 3 describes the method used for conducting the survey and Section 4 gives the galvanized steel amounts observed for each application. Section 5 gives statistical summaries as well as comparisons with other surveys.

2. BACKGROUND AND APPROACH

Every year corrosion of various steel materials costs the United States economy billions of dollars. As early as 1975 a study by the National Bureau of Standards ascertained that 15% of this cost was avoidable. The cost of material damage due to air pollution needs to be known in order to develop strategies for controlling atmospheric deposition which is the aim of EPA.

Much research has been conducted to study material damage resulting from air pollution. Guttman, (Haynie & Upham, 1970) for example, has shown that there is a direct correlation between the amount of corrosion of zinc panels and the measured atmospheric concentrations of sulfur dioxide (SO_2). It was also found that corrosion rates were significantly higher in urban areas than in rural locations. Guttman concluded that the two variables most important in corrosion are time of wetness and atmospheric sulfur dioxide concentration. Thus the ambient relative humidity is an important parameter.

The cost of material damage due to air pollution needs to be known in order to develop strategies which are intended to protect human welfare. But to obtain reliable estimates of the potential economic loss from damage of susceptible materials, the total quantities of materials in place and their distribution must be known. To obtain reliable results, the resolution of materials inventory should be consistent with that of the atmospheric deposition fields; much uncertainty still exists on the amount of exposed material.

2.1 Overview of Inventory Activities

Difficulties arise in determining the amounts of material in place because their distribution is neither uniform nor random either within a city or between cities. Koontz, et al. (1982) developed an empirical model for Baltimore and Saint Louis to relate exposed materials to variables measured at the census tract level. Dependent variables were wall and roof applications for residential, commercial, and industrial areas. Independent variables were population, and land use. Data on these variables was obtained from census publications, Sanborn maps, and ground truth surveys. The applications of roofs and walls included steel/metal materials among others. Their material composition estimates for the two cities in percentages of total exposed surface area for steel/metal were 2.52 % for wall and 1.78 % for roof applications.

Stankunas et al. (1981) performed a study in greater metropolitan Boston using aerial photographs and ground surveys. The data obtained were analyzed statistically to obtain estimates of the distribution of paint, galvanized metal, and structural concrete. They found that galvanized steel and concrete surfaces were relatively few when compared to painted surfaces. For the greater Boston area their estimate of galvanized surface was 2.76×10^7 m^2.

For suburban and rural areas, Atwater et al., (1985) examined photographs taken of houses in Charlotte, Lincoln, and Tucson. To estimate the amounts of exposed materials they used regression and confidence limits. Demographic and housing data were used in the analysis which excluded commercial, industrial, and multi-family dwellings. One of the 16 material types inventoried was galvanized steel, which they estimated at an average of 11.5 m^2 per house in fences and 1.0 m^2 in other applications. For guardrails, electrical transmission towers,

and fencing (non-residential) in both urban and rural settings their estimate of galvanized steel in place was 2.45 X 10^6 ft^2 (0.23 km^2) for the three cities.

Data on 1058 buildings including residential, commercial, industrial, and institutional were collected by the U. S. Army Corps of Engineers in Portland, ME, Pittsburgh, PA, Cincinnati, OH, and New Haven, CT (Lipfert, et al., 1986). They used a stratified random sampling technique developed by the U. S. Geological Survey (USGS) in which each strata was defined by land use and census data. Combining fence, sheet, gutters, and downspout applications for all building types, they found an average galvanized steel surface of 55.6 ft^2 per residential building and 1506 ft^2 per non-residential buiding. Data collected on the four cities were then used to perform within-city extrapolations and extrapolations to include 117 Metropolitan Statistical Areas (MSA) in 17 northeastern states.

In another study by Lipfert and Torpey, (1984) building materials were studied in high-rise central business districts. It was found that materials were more densely distributed where air quality and acid deposition are expected to be worse than in less densely populated areas and that there was a greater diversity of materials represented. Lipfert concluded that the condition of exposure to corrosive atmospheric agents was quite different for upper levels of high rise buildings and that deposition increased for a given level of air pollutant concentration.

On highway guardrails, Torpey and Lipfert considered each guardrail to have two components: the vertical and cross-member. The supporting posts were also of two types: weak post-3 inch I beam at 5.7 lb /ft, and the other a strong post-6 inch flange at 8.5 lb /ft. These authors reported that the steel type is uniform throughout the United States and the galvanized coating is applied in the field. In their findings, Torpey and

Lipfert stated that unpainted galvanized steel, unpainted weathering steel, and painted low carbon steel were the most popular types of guardrails. They note four types of guardrails: box, W-beam, uniform plate, and cable. They also note that constant repair and replacement of the barrier system is necessary because of atmospheric corrosion and vehicle impact. In New York they found 5,373 miles of guardrail, 75% of which was on state roads.

2.2 Maintenance Practices and Costs

On the subject of maintenance, Haynie (1970) researched the differential between bare aluminum and bare galvanized steel which he stated as corrosion avoidance cost. He noted that the difference between the present year and the previous year is the estimate of the amount of the present year's production used for replacement. Haynie concluded that because center cities have the highest average pollution levels, less bare galvanized steel is expected to be located here. Roofing, siding and guttering will continue to be bare galvanized steel for farm and light industrial buildings in suburban areas since they are exposed to less pollution.

In 1981 the zinc used for galvanizing worldwide was equal to two million tons. Among the major uses were farm building roofs, feed troughs, farm fencing and barbed wire. Galvanized steel was also used for transmission towers.

Haynie concluded that the cost of air pollution accelerated corrosion could be quantified within reasonable confidence limits. These costs were related to particular levels of pollutants and that transmission line towers represent structures for which considerable extra maintenance is expected.

The overall performance of galvanized steel in a specific environment is related to the cost of galvanizing in that context and then determining the life cycle costs. Galvanizing costs are a function of handling considerations plus the time required to bring the mass of immersed steel up to the galvanizing temperature. Painting is usually quoted on a cost per area basis. In a Texas gulf coast area in 1982, Seelinger (Coburn, 1984) determined that a three-coat paint system would cost $\$1.19/ft^2$. Thus, one needs to consider the yield of a longer service life and lower maintenance costs of an additional initial investment or a less expensive alternative coating which requires repetitive maintenance. Of course painting can be much more cost-effective in arid climates where hot-dip facilities require transport to distant baths.

Novak et al., (1984) studied data bases of residential construction practices. In a 1985 assessment of current damages from acid precipitation they estimated the amount of materials currently in place and made future projections about which materials might be susceptible to damage from acid deposits or air pollution. Their data was compiled from the U. S. Census Bureau and the National Association of Home Builders. A housing unit was defined as a house, an apartment, mobile home, trailer, a group of rooms, a single room, separate living quarters , a boat, or cave; even tents were included if used as a residence. In the North Central region, wood was the predominant building material used with lesser use of brick. In the East there was a greater amount of aluminum siding used. In the South Atlantic there was wide use of stucco. Findings showed that many states in the Northeast had higher exterior surface areas and were the main recipients of acid deposition. Connecticut had the largest average exposed wall surface area per home in the nation.

2.3 Methodology

The steps used in this study consisted of a field survey to locate bare galvanized steel in place, and an in-house survey to supplement the observations. The latter included telephone contacts, literature search, and aerial photography analysis.

Field activities were conducted in Cleveland, Atlanta, Dallas, and Sacramento. These cities were taken to be representative of their respective regions of the country. In each city, sections were located within the metropolitan area by land use. These were industrial and commercial (urban and suburban), and rural (farms).

Areas were chosen for analysis based on the availability of aerial photographs of the cities covering these land use categories. The choice was thus limited because only certain areas of the cities had been photographed. The catalog of available photos was compared with land use maps for photos that coincided with the required areas.

A total of eight applications were selected: roofing, siding, guttering, transmission line towers, fencing (chain link and farm), pole line hardware, guardrails, and storage facilities. These were expected to cover most, if not all, uses of bare galvanized steel. In each area surveyed extensive notes were taken of location, type of structure, dimensions, etc. Furthermore, 35mm photographs, which included a scaling rod, were taken for in-house analysis and calculation of surface area.

Using the field notes and photographs, surface area of galvanized steel were calculated by surveyed area. Aerial photographs were viewed under magnification to locate the structure within the survey area and obtain roof dimensions. These amounts, by application, were multiplied by land use area

within the metropolitan area to obtain a total for each land use category. The ground survey was augmented by a telephone survey of highway departments and literature search of electric utility data. An additional data set was obtained from Haynie (Personal Communication, 1988) on residential housing. Galvanized steel amounts for both multi-family and single family homes were extracted from this data set.

3. SURVEY METHOD

As noted in Section 2, this study was based on a selection of four cities which were taken as representative of four regions covering the 48 conterminous states of the United States. The regions were named Northeastern, Southeastern, Central, and Western and are illustrated in Figure 1.

In planning the survey, various methods were investigated to enhance coverage and find significant amounts of galvanized steel. One of the methods was remote sensing with aerial photographs. Image processing techniques suggested that spectral analysis of an area could be done using natural color photographs. To test the method, one such photograph at the scale of 1:36000 (approximately 5 mi^2) covering Costa Mesa, California was obtained, and a plastic overlay was constructed showing three levels of confidence for the presence of galvanized steel. Independently, a tour was made of the local wastewater treatment plant to confirm the analysis. But, in only a few cases was galvanized steel accurately plotted. Instances were found where galvanizing was plotted on the overlay but the surface was painted, or when galvanizing occurred but the analysis missed it altogether. This exercise revealed that the method is more applicable to minute color differences over a large area, such as the tracking of an oil spill at sea, and not as appropriate for single objects, as required in this work. It was then decided to perform ground surveys first and use the aerial photos to assist in the calculation of structure dimensions only.

Total land use coverage was estimated from the 1974 series of USGS land use maps. The land use areas of interest were colored and their area estimated by superimposing graph paper with squares of 1/10 inch size. With a scale of 1:250000 on the maps, each square covered approximately 403000 square meters.

Figure 1. Region Subdivisions in the Study

The total land coverage and individual land uses were estimated within an area enclosed by belt-line highways for each city. In the case of Sacramento, the estimate was made over all of Sacramento County. The Cleveland metropolitan area used for the survey on USGS land use maps was that enclosed by Interstate 271 on the east (following a line to Lake Erie directly north through Wickliffe from the intersection of I-90 and I-271), Interstate 80 on the south, and the Rocky River on the west. For Atlanta the area enclosed by the Interstate 285 beltline was used. The portion of metropolitan Dallas in the survey maps was enclosed by the Interstate 635 beltline on the north, east, and south. On the west, the lines were drawn by U.S. 77 and Mountain Creek until it intersected I-20.

An initial selection of ground survey areas was made by looking for groupings of industrial land use (USGS land use classification 13) near the downtown area and groupings of mixed industrial/commercial (15) or commercial (12) land use in the suburbs. In Atlanta, where no large industrial concentration existed, only mixed industrial/commercial sections were visited. The USGS maps were used on the assumption that zoning assignments within the metropolitan area have remained stable since 1974. Of course, this overlooks land development within city limits, giving an underestimate. Also, classifications 16 (mixed urban or built-up land) and 17 (other urban or built-up land) were ignored. This is another possible source of underestimation.

As noted previously, the selection was further narrowed by the availability of aerial photographs of the cities covering these land use categories. The best available photographs at a reasonable cost were high-altitude infrared photos from the EROS Data Center. For farm land use, a photograph outside the suburbs was selected.

Areas of 2 or 3 blocks to be ground surveyed were selected within the land use area appearing on the aerial photograph. The portion walked was selected upon arrival at the site, principally an access consideration. Any building or structure sighted with a galvanized coating was counted as a site. Galvanizing was determined from its characteristic coloring and granular appearance of the surface zinc crystals. A sketch was made to compare with on-site and aerial photographs. The structure's position was noted in relation to adjacent landmarks and, if access was possible, a photograph was taken along with a meter rod for scaling. If not accessible, the structure height was estimated and noted on the sketch. On a single building or structure, each application was noted separately. For example, the surface area of the roof of a galvanized shed was entered under the roofing application separately from the siding area. The area of galvanized chain-link fences were the estimated actual surface area of wire and posts.

The emphasis of the survey was to cover as many blocks as possible at the expense of missing small amounts of galvanized steel. It was found that the time required to obtain permission to enter every establishment would have considerably lessened the area covered. For example, access to the grounds of one major company was granted only reluctantly, with the stipulation that no pictures be taken. In another instance, a plant selected for survey on the aerial photo was involved in defense-related activities and no access was granted. So to cover as much area as possible, a sketch was usually made from nearby roads, a photograph was taken if considered necessary, and the building was plotted on the aerial photo. Furthermore, USGS topographical maps were obtained in each city to confirm exact building location. The sketch and photo were used to show which surfaces of the building were galvanized as well as dimensions of the building; the aerial photo was used to estimate roof area. All blocks visited were counted as part of the area surveyed, regardless of whether or not any galvanizing was found.

Raw data used for summing results from the field survey included photographs of selected galvanized structures, field notes of structures sighted and diagrams of building placement, USGS seven and a half minute quadrangle topographical maps, and corresponding aerial photographs. The field notes stipulated which buildings or surfaces on buildings were galvanized. Objects viewed on the field were located on the aerial photographs, and their corresponding locations noted on the topographical maps to obtain their position in UTM coordinates. The photographs with the meter rod in view were analyzed to estimate dimensions of the structure; these were also estimated from notes on the sketch. Then the aerial photographs were measured for the length and width of the roof using a magnifying reticle with divisions to one-tenth of a millimeter. On the 1:12000 photographs obtained for Sacramento, this gave a resolution of about two meters; for the 1:36000 USGS photos, a resolution of about five meters was possible. In very few instances was it not possible to locate the object, or find it too small to measure. From these measurements, calculations were made of the three dimensions of each structure: height, length and width (or diameter, if circular). The photographs were minutely studied in the case of special structures, such as towers or buildings with multiple roofs. This stage of the procedure was quite involved.

The data collected was then entered to a file of calculations for each structure surveyed. Data fields in this file contain the region in which the structure was seen, UTM coordinates referenced to the USGS map on which it appeared, type of application, census tract where located, tract population, a description code giving a general description of the type of structure, the USGS land use code number, the estimated surface area of the galvanizing, and general remarks. Sums were obtained from this data base sorted by region, land use, survey area and application.

Galvanized steel usage on farms was recorded by number of farms instead of land use since a count of the number of farms for 1985 was available from the Department of Agriculture. In this survey, no account was taken of farm fencing. In this report, the "fence" category for farms refers to formed sheet-metal gates.

4. REGIONAL SUMMARY

Results of the survey are summarized in Table 1 for non-residential (industrial and commercial) bare galvanized steel. Sparse applications (poles, guardrails, storage facilities) are grouped together as Other.

Table 1. Non-Residential Urban Bare Galvanized Steel Distribution

City	Survey Area km^2	Exposed Area m^2				
		Roofing	Siding	Guttering	Fencing	Other
Cleveland[1]	4.68	550	725	908.1	746.3	490.0
Indust.[2]	1.83	--	--	888	102.2	--
Mean[3]		--	--	177.6	34.1	--
StDev[4]		--	--	238.7	44.1	--
Commercial	2.85	550	725	20.1	644.1	490.0
Mean		183.3	241.7	6.7	64.4	49.0
StDev		200.3	236.1	3.8	55.2	41.3
Atlanta	2.32	7333	3580	1051	90.9	434.7
Indust./						
Commercial	1.30	7333	3580	1051	90.9	4.7
Mean		1833.3	1193.3	45.7	30.3	4.7
StDev		2007.8	1652.7	77.3	17.5	--
Commercial						
(Area 1)	0.60					395.0
Mean		--	--	--	--	131.7
StDev		--	--	--	--	119.3

(continued)

[1] subtotals for observations by application
[2] subtotals for observations in land use category by application
[3] mean area of observations
[4] standard deviation of non-zero observations

Table 1. (continued)

City	Survey Area km^2	Exposed Area m^2 Roofing	Siding	Guttering	Fencing	Other
Commercial (Area 2)	0.42					35.0
Mean		--	--	--	--	35.0
StDev		--	--	--	--	--
Dallas	4.77	11601	6365	384.8	484.4	401.6
Industrial	2.09	4305	2790	148.8	397.2	--
Mean		205.0	186.0	12.4	44.1	--
StDev		162.4	106.6	12.5	30.7	--
Commercial (Area 1)	0.48	6871.0	3575.0			
Mean		1374.2	1787.5	--	--	--
StDev		1301.8	2492.6	--	--	--
Commercial (Area 2)	2.20	425.0		236.0	87.2	401.6
Mean		212.5	--	118.0	43.6	80.3
StDev		208.6	--	137.2	37.3	75.3
Sacramento	4.71	49057	29318	32.9	200.4	988.7
Industrial	1.59	30765.0	15692.0			148.0
Mean		1060.9	603.5	--	--	148.0
StDev		1822.5	759.8	--	--	--
Industrial/ Commercial	1.54	16858.0	13586.0			
Mean		648.4	590.7	--	--	--
StDev		350.27	307.9	--	--	--
Commercial (Area 1)	0.88	230.0	11.7	21.6	193.0	522.0
Mean		230.0	11.7	7.2	96.5	104.4
StDev		--	--	7.6	51.6	147.4

(continued)

Table 1. (continued)

City	Survey Area km^2	Exposed Area m^2 Roofing	Siding	Guttering	Fencing	Other
Sacramento Commercial (Area 2)	0.70	1204.0	28.5	11.3	7.4	318.7
Mean		602.0	28.5	3.8	7.4	159.4
StDev		670.3	--	3.4	--	223.0

Table 2 shows bare galvanized steel on farms. The columns list the number of farms surveyed as well as the surface area of roofing, siding, guttering and fencing. Poles and storage facilities were combined as in Table 1.

Table 2. Farm Bare Galvanized Steel Distribution

City	Number of Farms	Exposed Area m^2 Roofing	Siding	Guttering	Fencing	Other
Cleveland[1]	17	915.0	470.0	--	321.8	36.6
Mean[2]		152.5	156.7	--	26.8	3.3
StDev[3]		134.1	141.5	--	7.4	1.1
Mean/Farm[4]		53.8	27.6	--	18.9	2.2
Atlanta	14	3020	44.0	--	109.0	--
Mean		232.3	22.0	--	13.6	--
St Dev		238.3	25.5	--	5.1	--
Mean/Farm		215.7	3.1	--	7.8	--

(continued)

Table 2. (continued)

City	Number of Farms	Exposed Area m^2				
		Roofing	Siding	Guttering	Fencing	Other
Dallas	12	2535	2255	--	130.8	689.2
Mean		158.4	187.9	--	32.7	172.3
St Dev		91.1	116.3	--	26.7	308.7
Mean/Farm		211.3	187.9	--	10.9	57.4
Sacramento	18	11968.4	821.0	2.2	186.4	88.5
Mean		266.0	136.8	2.2	186.4	11.1
St Dev		289.8	100.7	--	--	9.7
Mean/Farm		664.9	45.6	0.1	10.4	4.9

[1] subtotals of observations by application
[2] mean area of observations
[3] standard deviation of non-zero observations
[4] average area per farm

Some general observations in each city concerning gutters are in order.

- o Cleveland - barn gutters were usually painted. Almost all gutters in industrial areas were painted. No bare gutters were seen at all in the commercial area.

- o Atlanta - no bare galvanized gutters were seen in rural areas. Some gutters were left bare in city industrial and commercial areas.

- o Dallas - no rural structures had bare galvanized gutters. A few commercial structures showed bare galvanized gutters, but most were painted.

- o Sacramento - bare galvanized gutters were seen only on a few downtown commercial buildings. Almost all

commercial area gutters were painted. No industrial or farm buildings had gutters.

The estimate of surface area for electrical transmission towers was derived from published sources and were not counted during the field survey.

Although guardrail seen during the survey was included in the Other category in Table 1, significant amounts of guardrail exist along highways. An estimate of this amount, as well as that for highway fencing, will be presented in Section 4.4.

Sacramento had such a large amount of bare galvanized steel on street poles and fixtures, that it was considered necessary to give the results in the Pole Fixtures section. The estimation was made according to urban local street length instead of area surveyed. The large pole fixture area in rural Dallas was due to a microwave transmission tower and two amateur radio towers present in the area surveyed.

4.1 Residential Gutters, Flashing and Fencing

Several previous studies have been made to estimate residential galvanized steel usage. Studies were made by Koontz and McFadden (1982) for Baltimore, MD and St. Louis, MO; the U.S. Army Corps of Engineers of the Cold Regions Research and Engineering Laboratory (CRREL) for Portland, ME - Pittsburgh, PA - Cincinnati, OH and New Haven, CT; and by TRC Environmental Consultants for Los Angeles, CA (1985) - Charlotte, NC - Lincoln, NE - and Tucson, AZ (Atwater et al., 1985).

These studies sought to estimate the distribution of exterior building materials in residential areas by sampling in these cities and comparing between the cities for usage trends. The samples were taken from single and multi-family housing

units, and the materials surveyed included paint, masonry, stone, galvanized surfaces, galvanized fencing, and a few other miscellaneous materials.

Table 3 gives the estimates for residential exterior galvanized surfaces by adding the standard deviations of the galvanized percentage to the wall area mean given in Appendix B. These surfaces are principally siding and guttering with no roofing.

Table 3. Residential Exterior Galvanized Surface Area

	Galvanized Surface Area (m^2)		
	Low	Medium	High
Single Family	0.1704	0.8958	1.6212
Multi-Family	0.0213	0.0719	0.1225

4.2 Transmission Line Towers

Various sources were consulted to compile an estimate of the total mileage of electrical power transmission lines in the country. The primary source was the Directory of Electric Utilities (1986-1987 Edition) which lists all utilities in the United States. Circuit miles for transmission lines above 100kv were summarized from there. This voltage was selected since wooden poles are generally used for power lines below this magnitude. Figures taken from this source are only an estimate because reports from individual utilities were inconsistent in their grouping of transmission line categories. Also transmission lines are listed in circuit miles which is the length of all circuits on the line. This is always equal or

greater to the structural mileage, the total length of line segments connecting each transmission tower (Torpey, 1984). A single tower can carry from one to four or more circuits on its lines; the number of circuits was not listed in the directory.

Table 4 summarizes the calculations used in deriving an estimate for structural mileage and the total surface area of galvanized steel on power transmission line towers in the 48 states.

In the table, the first row is the total circuit miles of transmission line. The mean circuits per line was estimated from the table "Characteristics of Typical Transmission Lines" compiled from 75 utilities throughout the United States (Electric Power Research Institute, 1970) weighted by the transmission line length.

Another factor considered was how many towers were made of wood or aluminum as opposed to steel (all steel towers were assumed to be galvanized in this study). Again, the sample of 75 utilities gave a percentage of structure miles of transmission lines mounted on steel or other materials.

The product of mean towers per kilometer, transmission line length (km), and percentage of steel transmission towers is given as towers per region.

An average surface area per tower was taken as 1700 ft^2 or 158 m^2 per structure after Torpey and Lipfert (1984). The estimate of the surface area of galvanized steel transmission towers is given in Surface Area of Towers.

Table 4. Transmission Towers in Place

	Northeast	Southeast	Central	West
Transmission Line Lengths (circuit miles)	110,747	90,040	112,583	86,542
Mean Circuits	1.28	1	1.50	1.06
Transmission Line Length (km)	139,212	144,874	120,764	131,364
Percentage of Steel	83.5	100	39.7	73.8
Mean Towers per km	3.62	2.72	3.33	2.87
Towers per Region	420,797	394,058	159,651	278,237
Surface Area of Towers (m^2)	66.5×10^6	62.2×10^6	25.2×10^6	44.0×10^6

The value of 420,797 towers for the 17 states of the Northeastern Region compares reasonably well with the estimate of 263,714 towers in 6 states in that region given in another study (Mathtech, 1983).

Another comparison was made with results of a study done of transmission line length in New York (Torpey, 1984). The following table lists the New York power companies in the Directory of Electric Utilities.

Taking the factors for the Northeast region from Table 4, and dividing the sum of the circuit miles by 1.28 (mean circuits) gives mean circuits per line. Converting to kilometers and

multiplying by .835 for the percentage of steel towers and by 3.62 for the mean number of towers per kilometer gives 57,925 as the number of towers in New York State. This compares with 5.4 x 10^4 structures for New York in the Torpey report.

Table 5. New York Transmission Line by Utility

Utility	Circuit Miles
Niagara Mohawk Power Corp.	9080
Consolidated Edison Co. of New York	2894
Power Authority of the State of New York	1097
New York State Gas & Electric Corp.	884
Long Island Lighting Co.	782
Central Hudson Gas & Electric Corp.	304
Rochester Gas & Electric Corp.	204

4.3 Pole Fixtures

A large number of galvanized poles were seen in the street fixtures in downtown Sacramento, along with a variety of other coatings. The figures given in Table 6 summarize the surface area seen along one side of 6.2 kilometers of city streets. A small number of street fixtures in Cleveland were galvanized poles, although wooden or painted poles were the prevailing practice. The observations in Cleveland were made along 12.3 kilometers of downtown and suburban streets. All pole fixtures seen along city streets in Dallas and Atlanta were painted or wooden so that an analysis by street length is not applicable here.

Table 6. Sacramento and Cleveland Galvanized Pole Fixtures

	Pole Surface (m^2)	Length of Surveyed Street	Surface Area per Kilometer
Sacramento	433.9	3.1	139.97
Cleveland	43.2	12.3	3.51

4.4 Highway Guardrail and Fencing

A survey was made of highway departments of the 48 states to obtain guardrail and fencing mileage. Responses varied markedly. Some states had the figures readily available whereas others had never made a survey. Totals for highway guardrail were received from 27 states, having a mean of 2694.5 km of guardrail with a standard deviation of 2312.4 km. A breakdown by state is given in Appendix C.

Since not all states reported figures for their highway guardrail and fencing, some form of extrapolation was needed to supply the missing values for a national estimate. A multiple linear regression was performed to estimate these values. Few states reported the type of guardrail installed, so the average surface area of 0.765 m^2 of surface per meter of guardrail length was used as a typical value after Torpey and Lipfert (1984).

Factors considered as significant predictors of state guardrail and fencing installation were population, length of highway, land profile, and area of the state. Population to the year 1990 was extrapolated linearly using 1970 and 1980 census figures.

Total non-local highway mileage for the 48 states was obtained from a Federal Highway Administration publication Highway Statistics 1985. Fencing and guardrail on local streets was assumed to be minimal and could be ignored.

Land profile was an estimate of the hilliness of the land. Two methods were used to estimate this parameter. One was to take the average of the highest and lowest elevations of a state. The second was to estimate a relative factor from an elevation map of North America.

Equation 1 gives the estimating equation of guardrail as determined through the linear regression procedure described above for all 27 states

$$G = 1765.27 + 0.00016612\ P \qquad (1)$$

where,

G = estimate of guardrail length in kilometers,
P = state population.

The multiple regression model showed population as the only significant predictor at the 85% level. Some predictors were counter intuitive, e.g., decreasing guardrail length for increasing highway length. The failure of the other estimators to be included in the model shows that the available data is insufficient to reveal a significant correlation with known predictors.

When the regression was performed by regions using the four predictor variables, the relationships in Table 7 were obtained. The values in parentheses represent the standard error of the coefficient listed.

Table 7. Guardrail Length Regression Equations

Region	Equation
Northeast	G = -3806.460 + 0.00051975 P + 1851.075 E (1699.659) (0.0000926) (709.498)
Southeast	G = 14692.222 - 0.273585 H (6275.584) (0.15065)
Central	G = -723.302 + 0.0002712 P + 0.005432 A (824.144) (0.0001168) (0.002662)
West	G = 13005.700 + 0.2055753 H - 0.075028 A (794.452) (0.0160923) (0.005226)

where,

G = estimate of guardrail length in kilometers,
A = area of the state (km^2),
E = elevation factor,
H = length of non-local highway (km),
P = total population.

An illustration of the fit of these regression equations for each region is made in the following two figures. Here, the most significant independent variable is plotted against the regression line for guardrail length, along with 90% confidence limits of the regression. Observations are plotted as asterisks.

The regression fit for the Northeastern Region (Figure 2) was the best of the four. The figure shows a good relationship between state populations and guardrail length, as would be expected.

For the Southeastern Region, however, the fit was poor; with the wide 90% confidence limits, there was no significantly better predictor than the average. This is illustrated in Figure 2 which shows a negative slope for the regression between guardrail length and highway length. Similar results are noted in the Western Region (Figure 3).

A fair fit between the predictors and guardrail length was obtained for the Central region. Figure 3 illustrates this relation between state area and guardrail length. The fit with area alone is weak, but is improved with the addition of population as an additional predictor.

In our calculations, one kilometer of guardrail has a surface area of 765 m^2. Multiplying the equation for the Northeast Region by this factor gives

$$G = -2911941.9 + 0.39760875\ P + 1416072.375\ E \qquad (2)$$

where P and E are as given previously.

The average of five states in the Southeastern Region is 3353.4 km of guardrail with a standard deviation of 1581.4, so that for the nine states in the Southeastern Region, the estimate is 30,180 km of guardrail. Multiplying by 765 m^2, the estimate is 23.09 $km^2 \pm 10.89\ km^2$.

For the Central Region, multiplying by the factor 765 gives the following equation.

$$G = -553326 + 0.20747\ P + 4.1555\ A \qquad (3)$$

where P and A were given earlier.

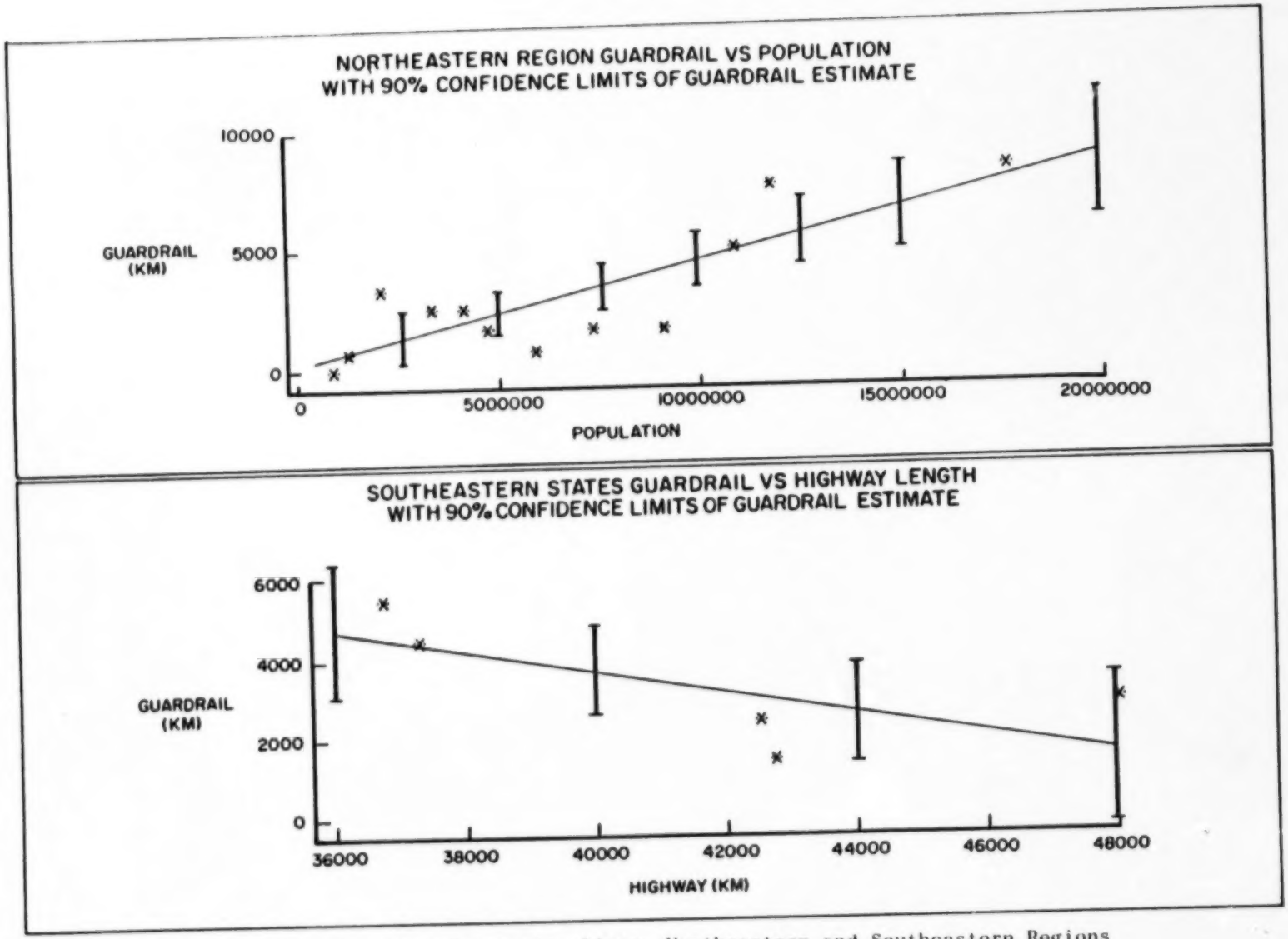


Figure 2. Guardrail Regression Lines, Northeastern and Southeastern Regions

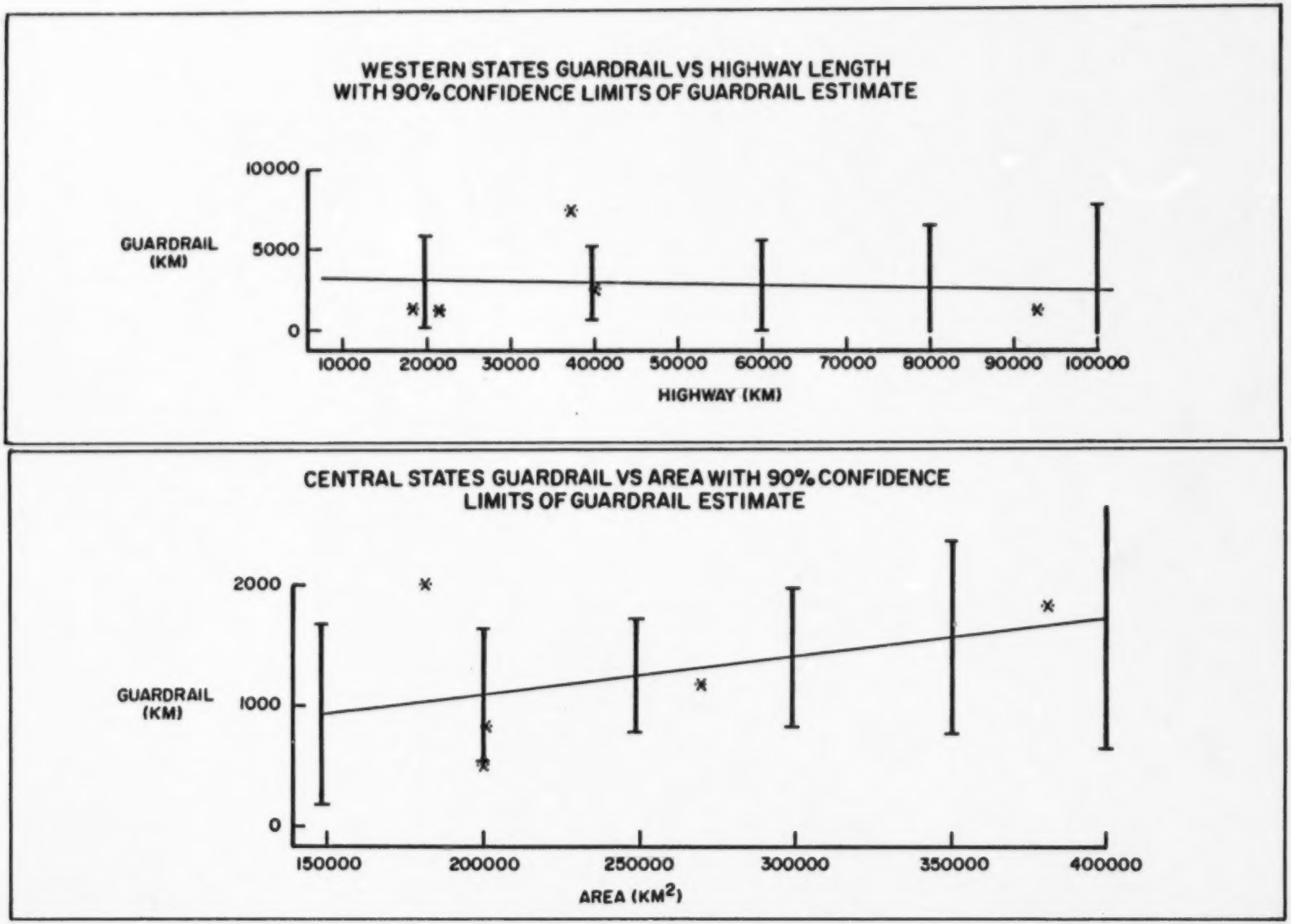


Figure 3. Guardrail Regression Lines, Western and Central Regions

For the Western Region, the average of the five state guardrail amounts reported is 2516.8 km of guardrail with a standard deviation of 2594.6 km. For the eight states in the Western Region, multiplying by the 765 factor, the estimate is 20,130 km of guardrail, which is equivalent to 15.40 km^2 ± 17.86 km^2 surface of guardrail.

The figures for fencing were even less extensive than those for guardrail. Highway fencing lengths were received from 17 states with a mean of 3275.3 km and a standard deviation of 3594.4 km. The same predictor variables used for the guardrail estimate were used with fencing. However, the only significant predictor was state area and this at the 50% significance level. So, an average of the fence values reported by the states was used for an estimate.

To calculate surface area, measurements were made of galvanized chain link fencing in the Costa Mesa, California area. From these measurements an average value of 0.247 m^2 of exposed surface per m^2 of fence were obtained. For the height, an average of 2 m was used. This gave 494 m^2 of wire surface for every kilometer of fence. Barbed wire along highways was taken to have a diameter of 2.5 mm and to have six strands, which gave an average surface area of 47.1 m^2 per kilometer of barbed wire fencing. Some states were able to break down their totals into lengths for chain-link and barbed wire fencing, and this was taken into consideration. The result was an average of 9.1×10^5 m^2 surface of galvanized chain-link or barbed wire highway fencing per state.

Barbed wire perimeter fencing on farms was not included in the survey. Amounts observed were too extensive to include in every case, as opposed to galvanized steel on buildings and other structures, which were more easily counted.

5. IN-PLACE SUMMARIES BY APPLICATION

The results of the Aerocomp survey for non-residential urban galvanized steel are listed in Table 8. The figures are the total surface area seen in each city for each application.

Table 8. Non-Residential Urban Galvanized Steel Distribution

City	Survey Area (km^2)	Exposed Area (m^2)				
		Roofing	Siding	Guttering	Fencing	Other
AEROCOMP						
Cleveland	4.68	550	725	908.1	746.3	533.2
Atlanta	2.318	7333	3580	1051	90.9	434.7
Dallas	4.77	11601	6365	384.8	484.4	401.6
Sacramento	4.712	49057	29318	43.9	200.4	988.3

As noted earlier the category of Other includes pole line hardware, storage facilities, and non-highway guardrail. The wide data variation within one region in the CRREL data set suggests that regional differences found in the present survey may be artificial.

A comparison was made between this survey and that performed by Atwater et al., (1985), of TRC Consultants, also summarized by Haynie. Results are given in Table 9 along with the Aerocomp survey, given as average surface area of application per farm.

Table 9. Bare Galvanized Steel Distribution per Farm

City	Number of Farms	Exposed Area (m^2) Roofing	Siding	Guttering	Fencing	Other
TRC						
Charlotte	5	273.8	80.6	0.91	50.49	0.0
Lincoln	5	156.5	125.0	10.62	62.76	0.0
Tucson	5	50.4	65.4	0.0	53.82	42.3
AEROCOMP						
Cleveland	17	53.82	27.65	0.0	18.93	2.15
Atlanta	14	215.7	3.14	0.0	7.79	0.0
Dallas	12	211.3	187.9	0.0	10.9	57.43
Sacramento	18	271.4	45.61	0.12	10.4	4.92

Values here show more consistency between regions than between regions in urban areas. This suggests that farm national coefficients would be more applicable to estimate galvanized steel distribution than urban areas.

A regression through the origin was done using CRREL and Aerocomp data (Table 10). Tabulated values are regression coefficients and corresponding standard deviations.

A t-test procedure using the Statistical Analysis System was used to evaluate difference of means between these samples (Tables 10 and 11). With the exception of farm fencing, no significant difference at the 90 % confidence level between sample means was found. However, the Aerocomp values tend to be lower; this may result from the survey method, which sometimes

overlooked small surfaces. On fencing, the CRREL survey recorded plane surfaces, whereas Aerocomp calculated the actual wire surface of fencing. Perimeter fencing on farms was not included in the Aerocomp survey, so that a significant difference exists between the regression coefficients for the Aerocomp data and those of TRC at the 99 per cent confidence level.

Table 10. Regression Through Origin of Galvanized Steel for Non-Residential Urban Land Area (m^2/km^2)

Study	Roofing	Siding	Guttering	Fencing	Other
Aerocomp	4237±2448	2494±1463	121±69	96±28	140±31
CRREL	11428±7007	17796±14095	217±101	3475±1345	

The regression coefficients and standard deviations of Aerocomp and TRC are given in Table 11.

Table 11. Regression Through Origin of Galvanized Steel for Farms (m^2/farm)

Study	Roofing	Siding	Guttering	Fencing	Other
Aerocomp	11.92	3.77	0.0023	0.786	0.854
	± 3.37	± 2.94	± .0018	±.142	±.92
TRC	19.02	10.37	0.391	13.106	1.80
	± 7.80	± 2.96	±.439	±1.9	± 1.61

The approximate area of non-residential urban land enclosed by interstate highways as described in Section 3 is given in Table 12.

Table 13 gives estimates of galvanized steel in the four cities, found by multiplying the galvanized material observed by the non-residential urban land area.

Table 12. Non-Residential Urban Land Area by City

City	Non-Residential Urban Land Area (km^2)
Cleveland	124
Atlanta	100
Dallas	95
Sacramento	149

Table 13. Estimate of Galvanized Steel for Non-Residential Urban Land Area (m^2)

City	Roofing	Siding	Guttering	Fencing	Other
Cleveland	1.5×10^4	1.9×10^4	2.4×10^4	2.0×10^4	1.4×10^4
Atlanta	3.2×10^5	1.5×10^5	4.5×10^4	0.4×10^4	1.9×10^4
Dallas	2.3×10^5	1.3×10^5	0.8×10^4	1.0×10^4	0.8×10^4
Sacramento	1.6×10^6	9.3×10^5	0.1×10^4	0.6×10^4	3.1×10^4

6. SUGGESTIONS FOR FURTHER STUDY

Certain steps can be taken to enhance this study and these are given below.

Visually, some roof ventilation equipment appeared to be galvanized steel. Of course, there was no access to roofs in order to count structures. Permission could be obtained, however, to survey roof structures in order to extrapolate by roof area over the number of buildings visible in aerial photographs.

Interstate highway sign posts are galvanized. A survey of state transportation departments could be made for the number and type of highway signs on interstate and major state highways.

The most common galvanized steel application in all areas was chain-link fencing. This was so extensive that a separate study for fencing alone would be needed to estimate its true extent.

7. REFERENCES

Atwater, Marshall A., Douglas R. Murray, and John E. Yocom, 1985: Determination of Materials Distribution in Suburban and Rural Areas. TRC Environmental Consultants, Inc. Report on Contract 68-02-3742; Atmospheric Sciences Research Laboratory, Research Triangle Park, NC. 168 pp.

Coburn, Seymour K., 1984: Cost Effectiveness of Hot-Dip Galvanizing for Exposed Steel, Transportation Research Board, Washington, D.C., 22 pp.

Directory of Electric Utilities, 95th Edition, 1987: McGraw Hill Publications, New York.

Electric Power Research Institute, 1970: Transmission Line Reference Book, 345 KV and Above. Electric Power Research Institute, Palo Alto, CA: 16 pp.

Federal Highway Administration, 1985: Highway Statistics. U. S. Department of Transportation, Washington, DC.

Haynie, F. H. and J. B. Upham, 1970: Effects of Atmospheric Sulfur Dioxide on the Corrosion of Zinc, National Association of Corrosion Engineers, Raleigh, NC. 5 pp.

Koontz, Michael D., James E. McFadden, and F. H. Haynie, 1982: Estimation of Total Surface Area and Spatial Distribution of Exposed Building Materials From Commonly Available Information for U. S. Metropolitan Areas, Paper presented at the Second International Conference on the Durability of Building Materials and Components, Gaithersburg, MD. 16 pp.

Larrabee, C. P. and O. B. Ellis, 1959: Report of Subgroup of Subcommittee VII, on Corrosiveness of Various Atmospheric Test Sites as Measured by Specimens of Steel and Zinc, Proceedings of American Society for Testing and Materials 59: 183.

Lipfert, F. W. and M. R. Torpey, 1984: Methods For Materials Inventorying in High-Rise Central Business Districts, Brookhaven National Laboratory, Upton, Long Island, NY. 31 pp.

Lipfert, F. W., R. Horst, R. Livingston, C. J. Mery, and S. Sherwood, 1986: The Distribution of Common Construction Materials Sensitive to Atmospheric Corrosion, Brookhaven National Laboratory, Upton, Long Island, NY. 34 pp.

Mathtech, Inc., 1983: Benefits of Reduced Materials Damage Due to Local Reductions in SO_2 Concentrations: A Six State Study. Mathtech, Inc., Princeton, NJ. 9 pp.

Novak, K. M., E. A. Coveney, M. R. Torpey, and F. W. Lipfert, 1984: Data Bases on Residential Construction Practices, Brookhaven National Laboratory, Upton, Long Island, NY. 31 pp.

Stankunas, Alexander R., Dennis F. Unites, and Edward F. McCarthy, 1981: Air Pollution Damage to Man-made Materials, TRC Environmental Consultants. Paper presented at the 74th Annual Meeting of the Air Pollution Control Association, Philadelphia, PA. 8 pp.

Torpey M. R. and F. W. Lipfert, 1984: Methods For Estimating Materials in Infrastructure Elements, Brookhaven National Laboratory, Upton, Long Island, NY. 33 pp.

TRC Environmental Consultants, Inc., 1985: Assessment of Materials Damage and Soiling from Air Pollution in the South Coast Air Basin: Final Report for the California Air Resources Board. Agreement A2-120-32. TRC Environmental Consultants, Inc., East Hartford, CT.

U. S. Department of Agriculture, 1986: Agricultural Statistics. Volume 1., U. S. Government Printing Office, Washington, DC: 2 pp.

APPENDIX A.

DESCRIPTION OF SURVEY ACTIVITIES

The sections that follow describe qualitatively certain observations made during the survey. Each city is discussed separately.

SACRAMENTO

Sacramento was the first city surveyed and the method used there served as a pattern for the other cities.

Commercial

A count of street lights, sign posts, and other galvanized steel street fixtures was made in downtown Sacramento. A variety of materials was observed even on the same street: galvanized steel, aluminum and painted structures. Next, a survey was made of an area consisting principally of office buildings north of the state capitol. In that area little galvanized steel was found and this only on older buildings. No buildings which appeared to have been constructed in the last 10 years had any exposed bare galvanized steel. The only large structures were a parking garage roof and a steel awning around an abandoned railway station. Recent constructions were two microwave towers with their associated supports. Other minor galvanized structures were ventilation pipes and rainspouts on older buildings.

Fencing was the one application common in commercial areas. It was much too common to include every occurrence in the survey, so that it was assumed that any open or parking area, or any border between open areas appearing on the aerial photo was fenced. Several measurements were made of typical fence

dimensions. The support poles used in fencing in the Sacramento area appeared to be made of aluminum and were not included in the inventory.

One reason for the lack of galvanized steel in recent structures had to do with construction practices. A local builder affirmed that there was a code which required all bare exposed metal to be painted. A Sacramento County inspector, after a search of the county codes, stated that there was no such law. He explained that at times certain practices are followed for so long that they are assumed to be part of the law, and this appeared to be the case here. Regardless of the reason, commercial buildings were almost devoid of galvanized steel.

Other commercial areas examined were shopping centers and the state convention center. The only galvanized steel seen at the shopping centers were lamp posts and a few railings at loading areas. The convention center had much fencing and a few incidental galvanized siding and guttering structures on utility buildings. However, the only area surveyed here was the parking lot and adjacent structures, as the grounds were closed on the day of the survey.

Some roof ventilation equipment appeared to have been galvanized steel. Of course, there was no access to any roof in order to verify distant views or count structures and these were omitted from the inventory.

The owner of an air-conditioning shop stated that he had not seen any deterioration of exterior galvanized surfaces. The corrosion he had seen was due to improperly operated furnaces which allowed moisture buildup inside the duct. He felt corrosion due to air pollution was nil, in that he knew of structures which had been put up in the 1940's which were still serviceable and showed no deterioration.

A special case of a commercial area was the Executive Airport, which had several buildings made of galvanized steel. The USGS maps list this type of land usage as transportation and this area was lumped together with commercial land for the purposes of this survey.

The downtown section visited covered an area of approximately 0.25 square miles. The commercial and exposition area covered approximately 0.6 square miles.

Industrial

Industrial areas showed much more usage of galvanizing. Within the industrial survey area, the plant grounds of one major company were surveyed. The plant was opened in 1947, and a number of galvanized buildings from that time were still in service, but more recently constructed buildings had been painted. Other industries in the area were small concerns which dealt with sheet metal, steel construction, and car body work. Many of their buildings and sheds were galvanized steel. There was very little rusting or deterioration evident on any of these buildings.

Farms

A rural area directly south of Sacramento was visited next. Large buildings on 18 farms on both sides of a rural road for a distance of about 3.5 miles were visited individually. Inspection of smaller buildings was done only when permission was granted to enter the farm grounds. In some instances there was no one on the grounds so that only a plot of galvanized buildings on the aerial photograph was made. Again, most new construction was painted in some manner, but there were many galvanized structures which were quite old and were still serviceable.

Aluminum was another a common material for barn roofs and other structures. Other commonly observed galvanized steel structures were heating fuel tanks -- almost every farm had at least one.

As was the case in the city, deterioration of the galvanizing was the exception rather than the rule in rural areas. A few buildings were rusting, but usually all galvanized structures retained their zinc coating. One farmer mentioned that the roof of his barn had come from a dairy farm demolished to make room for the present site of the Executive Airport. He did not know how many years the farm had been there, but he had taken the roof from that barn and set it on his own some 30 years earlier. Only three years previously did he finally have the roof painted. So, he guessed that perhaps 40 years had gone by before the roof needed a coating.

DALLAS

Industrial

An industrial area near downtown Dallas had a significant amount of galvanized steel. Most of the structures were small buildings for use by local businesses. These buildings appeared to be older than those in the downtown area and showed some surface deterioration, although little had gone to the extent of rusting. No attempt to coat or protect the surface was apparent.

Commercial

In the downtown commercial area, almost all steel structures were painted, including poles for street lights and signs. A few structures were of bare galvanized steel and showed no signs of rust. One was a roof and the other was a tank mounted behind a bakery. However, these were recently constructed. A few flue

pipes and gutters behind several older buildings were of bare galvanized steel and showed some rust, but were still serviceable.

Commercial areas near downtown were almost totally devoid of bare galvanized steel. Aluminum or painted or coated surfaces were the universal practice. A few bare galvanized steel gutters were found, however. Contrary to expectations, the suburban commercial area had several sizable bare galvanized buildings and roofs.

A local roofer stated that he had seen more rust on the undersides of galvanized roofs than on the top. If an outer surface did rust, he stated that he would repaint it. But, if galvanized steel was specified in new construction he would pre-paint it.

Farms

In rural areas, practically every farm had a galvanized shed, gate or fence. Little deterioration was apparent, but many of the farms in the area had been occupied only in the last 10 years. Deterioration of the galvanizing and rust became apparent only after a much longer period.

One farmer said that he had bought his farm in 1950 but had lived elsewhere and had moved onto the property only in 1977. A chicken coop in back of his house dated from his purchase and it showed general deterioration of the galvanized surface with a few rust spots. A newer roof on the coop dating from his moving onto the farm had almost no deterioration. This farmer had made one attempt to coat a galvanized roof; a salesman had convinced him to try a sprayed aluminum treatment. However, that coating had caused rusting in less than three years. So, he concluded that leaving all galvanized structures bare was best.

ATLANTA

Industrial

The portion surveyed in the Atlanta industrial area had few buildings of bare galvanized steel. Almost all recent buildings were either painted or of coated aluminum. However, galvanized flashing around the perimeter of building roofs with accompanying gutters was a common feature in the industrial area.

Commercial

In commercial areas, no galvanizing on buildings was observed. The only common galvanized structures were chain-link fencing and a few guardrails in parking lots. One shopping center had bare galvanized light poles, but most light poles were either wood or were of painted metal. A few poles for suspending traffic lights were of bare galvanized steel. A local construction engineer who was interviewed stated that in any new building, galvanized steel would not be recommended due to aesthetic considerations.

Farms

In rural areas, roofs showed considerable deterioration. Many farms were abandoned and buildings had fallen into disrepair. Often, so much rust had accumulated that it was impossible to tell what the original coating had been. New construction in the rural area did not favor the use of bare galvanized steel. One ranch was quite new and every metal surface was painted. Only one painted galvanized barn had minor rust in a few places after a period of 10 years.

One homeowner had a shed with different galvanized sheets placed at different times. The older part of the roof had been put up 35 years earlier and showed considerable rust. The newer roof was only 10 years old and was relatively rust-free. Some homes had galvanized roofs which were preserved by painting. One homeowner did his repainting every four or five years.

Barbed wire fencing was extensively used, but had rusted in all locations. Another common rural galvanized structure was gates for livestock.

One farmer had opened a small business inside a Quonset hut, made entirely of bare galvanized steel. In six years, the structure showed no rusting whatsoever. The same farmer had a number of galvanized sheds on his farm which had been in use for some 30 years. His usual practice was to paint over it at installation time and then repaint as needed.

CLEVELAND

Industrial

In the suburban industrial areas, almost no large structures of galvanized steel were seen. An exception was a large refrigeration unit. The only common bare galvanized structures were chain-link fencing and guardrails used in parking areas.

The need to re-paint galvanized structures was apparent in many areas in that the paint had peeled down to the galvanized surface. This was the case even on relatively new buildings (10 years or less).

In the urban industrial area, exposed galvanized steel was seldom seen. A few ventilators and gutters were bare galvanized steel but they were the exception and they appeared to have been

installed recently since no rust was observed. In the industrial areas, it appeared that if any steel structure was exposed for more than a few years, it would rust regardless of the coating used. A number of buildings showed neglect in that many structures were rusted, even beyond recognition of what the original coating had been.

Chain link fencing was often rusted, but there were sections which appeared undamaged having possibly been only recently installed.

Almost all highway signs and lightpoles along Interstate 71 had a rusty color. On certain sides of the poles, the galvanizing appeared intact, but along other sides, the surface was completely covered with a light rusty color. Those portions of the pole facing an automotive manufacturing plant and two major steel producers showed the rust.

Commercial

Painting was used for all metal surfaces in Lakewood, Ohio, an urban commercial district. No exposed galvanized steel appeared at all in this area. Street lights and signs were mounted on wooden or painted poles.

A local builder explained that a baked enamel surface was the material of choice in commercial buildings today. He was not aware of any codes stipulating surfaces for steel.

Farms

There was very little bare galvanized steel in the rural areas. One galvanized garage had remained uncoated and significant rust was showing on the roof in only eight years. On another farm, a barn roof had been left to rust completely

over a period of 25 years. This roof had been repaired by replacing rusted sections with new pieces of sheet galvanized steel.

Ohio barn roofs often were made of galvanized steel, but were coated with a silvery colored paint; exposed galvanized steel was quite rare. In places the paint, not re-coated recently, had peeled to the point of exposing the galvanizing.

Almost all of the rural galvanized buildings were older structures. The more recent buildings were made of coated aluminum. A roofing and siding supplier near Burton, Ohio, supplied only aluminum for construction and said they knew of only one supplier in the area who carried steel siding and roofing.

APPENDIX B.

RESIDENTIAL GALVANIZED SURFACES

Given here are data summarized by Haynie for the residential surface area of galvanized steel from the study by Atwater et al. (1985).

Table B1. Single Family Residential Exterior Materials

City	Walls		Fencing		Galvanized	
	Surface (m^2)	Error (m^2)	Surface (m^2)	Error (m^2)	Surface (%)	Error (%)
Pittsburgh	288.1	9.30	0.30	0.30	0.44	0.13
New Haven	387.0	28.30	3.00	1.30	0.00	0.00
Portland	325.0	38.40	0.00	0.00	0.60	0.27
Charlotte	426.5	29.30	7.10	1.60	0.05	0.03
Lincoln	386.2	39.10	14.10	3.30	0.42	0.20
St. Louis	280.4	11.00	N	N	0.11	0.05
Tucson	274.9	25.30	13.30	3.50	0.42	0.14
Los Angeles	249.2	42.60	4.60	N	0.15	0.06
Mean	327.2		6.06		0.2738	
St Dev	64.9		5.77		0.2217	

Table B2. Multi-Family Residential Exterior Materials

City	Walls		Fencing		Galvanized	
	Surface (m^2)	Error (m^2)	Surface (m^2)	Error (m^2)	Surface (%)	Error (%)
St Louis	116.4	11.00	N	N	0.11	0.05
New Haven	91.5	6.84	0.40	0.21	0.00	0.00
Portland	100.7	6.64	2.79	1.55	0.09	0.07
Pittsburgh	101.7	24.60	0.00	0.00	0.04	0.04
Baltimore	88.9	6.00	N	N	0.12	0.08
Mean	99.8		1.06		0.0720	
St Dev	10.8		1.51		0.0507	

N = Data Not Available

APPENDIX C.

HIGHWAY GUARDRAIL LENGTH

State-reported figures of guardrail length are given in the table below. Some states provided no information and are not listed here.

Table C1. Highway Guardrail Length

STATE	LENGTH (km)	STATE	LENGTH (km)
California	1128.0	New Jersey	1569.0
Colorado	1245.8	Nebraska	835.5
Connecticut	2819.4	North Carolina	2779.8
Florida	2409.1	Ohio	4630.9
Idaho	670.6	Oregon	2386.5
Illinois	2136.1	Pennsylvania	7627.2
Kentucky	4741.1	Rhode Island	370.1
Maine	1195.4	South Dakota	500.2
Michigan	1529.5	Tennessee	1256.7
Maryland	2353.4	Utah	833.6
Massachusetts	1126.5	Virginia	5581.2
Missouri	1920.2	Washington	7563.6
Montana	1800.5	West Virginia	3708.1
New York	8647.0		